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U. S. DEPARTMENT OF AGRICULTURE.
DIVISION OF ENTOMOLOGY.
BULLETIN NO. 24.

THE BOLL WORM OF COTTON.

A

REPORT OF PROGRESS

IN A

SUPPLEMENTARY INVESTIGATION OF THIS INSECT.

MADE UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

F. W. MALLY.

(PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.)

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LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Division of Entomology,
Washington, D. C., February 27, 1891.

Sir: I have the honor to submit for publication Bulletin No. 24 of this Division. It consists of a preliminary report upon the special investigation of the Cotton Boll-worm (*Heliothis armigera* Hübn.) which was authorized by Congress in the bill making appropriations for the use of the Department for the fiscal year 1890–'91.

Respectfully,

C. V. Riley.
Entomologist.

Hon. J. M. Rusk,
Secretary of Agriculture.

INTRODUCTION.

The present bulletin consists of a report made by Mr. F. W. Mally upon the progress of the special investigation of the Cotton Boll-worm which has been carried on under the Division since the appropriation became available, July 1, 1890. Mr. Mally has had charge of the minor details of the investigation, and has been constantly in the field since last July. He also summarizes the results obtained by Messrs. McNeill and Booth. The Boll Worm was treated at some length in the Fourth Report of the U. S. Entomological Commission, and the chief object of the present investigation was to conduct further experiments with remedies, as well as to verify the value of those already employed. A thorough series of experiments has been planned with the diseases of Heliothis and allied insects, in the hope of being able to practically utilize them. Incidentally I have desired to ascertain new facts, if possible, and to verify or disprove what has been previously written in connection with the life history and habits of the species.

The observers have all been hampered in their work by the unexpected lack of material. The funds were not available until the season was three-fourths spent. The observations so far made will, therefore, have to be supplemented the coming spring and summer. It transpires that the ravages of the Boll Worm have been overestimated, and that while from 20 to 30 per cent of the bolls are damaged in an average season in Mississippi, only about one-third of this damage is done by this insect. Several other species which do work somewhat similar to that of the Boll Worm are treated in this report. Some new food-plants have been found, and a careful study has been made of the habits and life history which are here treated with more care and detail than has heretofore been given to the subject. Two new parasites have been discovered, and observations have been made which show that the egg parasite (*Trichogramma pretiosa* Riley) is an extremely important factor in the economy of this insect, as it is, also, in that of the Cotton Worm (*Aletia xylina* Say), and the Grass Worm or Fall Army Worm (*Laphygma frugiperda* Smith & Abbott). A careful count shows that 84 per cent. of the eggs were destroyed by this useful parasite. All of the old remedies have been once more tested, and the use of corn as a trap crop is again shown to be one of the most satisfactory means of protecting the cotton crop. The old subjects of attracting the moths to lights and poisoned sweets have once more been carefully considered, and my former conclusions have been confirmed, that there is little to be hoped for from either of these methods. The pyrethrum experiments, from which I had much

hope, have not proved very favorable, while experiments with a large series of other vegetable insecticides have given no practical results as yet.

The experiments with contagious diseases can not be reported upon in any detail at the present time; but a large number of cultures of several diseases of the Imported Cabbage Worm, the Bronzy Cutworm and of two other Noctuids have been secured and carried through the winter. What may prove to be a specific disease of the Boll Worm has also been discovered, and cultures have been obtained. It results from the few experiments made that the Boll Worm is probably susceptible to the Cabbage Worm disease, but positive statements can not be made until these experiments are confirmed by those of another season. A bacteriological laboratory has been established at Shreveport, Louisiana, and has been well fitted out with the necessary apparatus, so that work in this direction the coming season will not be hampered, except in the case of an unexpected paucity of Boll Worms.

C. V. R.

LETTER OF TRANSMITTAL.

SHREVEPORT, LOUISIANA, *February* 19, 1891.

SIR: In compliance with your request I have made out a report of progress of an investigation of the History and Habits of the Boll Worm (*Heliothis armigera* Hübner), carried on under your instructions since July, 1890, and submit the same herewith. The treatment of the various subjects is not at all in detail and has only been made complete enough to give an adequate conception of what has been done, the present status of the investigation, and what remains to be accomplished in the future.

Very respectfully yours,

F. W. MALLY,
Assistant Entomologist.

Dr. C. V. RILEY,
United States Entomologist.

THE BOLL WORM OF COTTON.

DESTRUCTIVENESS.

The damage to corn by the Boll Worm is difficult to estimate, owing to the nature of the attack. Its ravages in the "bud" of the young plants and later in the ends of the ears taken collectively no doubt are considerable, though no definite per cent can be given. Tomatoes, cucumbers, and melons also suffer more or less seriously from its ravages. It is the attack upon cotton which is considered most serious and supposed to be of great proportions. To determine the amount of damage to cotton in the regions visited the past season the following studies were made. The first was made August 14, in a large field of upland cotton surrounded by woods. Two rows were taken at random in the field; the first was rank high cotton, the second a smaller growth. About 10 feet of each row were marked off and all the bolls on the plants in each counted. (See Table I.)

TABLE I.

Row.	Good bolls.	Loss by Boll Worm.	Loss by other causes.	Total.
1	290	2	95	389
2	270	1	43	314

The next study was made September 16, in a small field of rank bottom-land cotton. The first five plants were taken at random, the next fifteen successively in one row. (See Table II).

TABLE II.

Plant.	Good bolls.	Loss by Boll Worm.	Loss by other causes.	Total.
1	40	7	5	52
2	21	2	13	36
3	4	2	0	6
4	30	3	20	53
5	34	10	34	78
6	19	11	20	50
7	18	2	0	20
8	25	9	15	59
9	17	9	12	38
10	70	6	9	85
11	33	7	1	41
12	42	4	9	55
13	49	0	4	53
14	3	0	0	3
15	10	0	0	10
16	33	2	2	37
17	25	2	11	38
18	72	2	24	98
19	17	0	3	20
20	7	0	0	7
Total	579	78	182	839

September 17, a similar study of twenty-one successive plants was made in another portion of the same field. (See Table III).

TABLE III.

Plants.	Worms.	Good bolls.	Loss by Boll Worm.	Loss by other causes.	Total.
1	1	33	4	13	50
2	1	23	1	1	25
3	2	60	3	2	65
4	0	30	3	1	34
5	2	41	3	8	52
6	0	65	3	0	68
7	1	11	1	4	16
8	0	29	1	1	31
9	0	53	3	1	57
10	2	53	5	1	59
11	1	24	5	14	43
12	0	63	6	25	94
13	0	24	0	5	29
14	0	19	8	3	30
15	0	23	9	12	44
16	3	88	13	30	131
17	0	22	4	5	31
18	0	36	0	2	38
19	0	14	0	0	14
20	0	20	0	11	31
21	0	49	6	39	94
Total.	13	780	78	178	1,036

Table I should not be included in the table of percentages, since its data were obtained early in the season, before the Boll Worm had really become well established in cotton. Omitting table I we have the following table:

TABLE IV.

Percentages from Tables II and III.

Table.	Good bolls.	Loss by Boll Worm.	Loss by other causes.	Total loss.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
II	.690	.092	.218	.310
III.	.753	.075	.172	.247
Average.	.7215	.0835	.195	.2785

The four preceding studies were made by a count of what was actually found on the plants at the time of observation. September 18 only bolls and forms which had fallen were collected and examined. The result is given below:

Number bored by Boll Worm	167
Number shed from other causes	362
Total	529

Taking the average of the total loss found in the same field on the two preceding days, and tabulated as Tables II and III, and again in Table IV, these 529 bolls may be considered as equivalent to the count-

ing of 1,900 bolls by the method of Tables II and III. This study may therefore be given as below:

TABLE V.

	Number.	Per cent.
Good bolls	1,371	.722
Loss by Boll Worm	167	.088
Loss by other causes	362	.190
	1,900	1.000

Averaging this result with that of Table IV we have the table given below as the result:

TABLE VI.

Data.	Good bolls.	Loss by Boll Worm.	Loss by other causes.	Total loss.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Table V	.7215	.0835	.195	.2785
Study V	.722	.088	.190	.2780
Average	.72175	.08575	.1925	.27825

The above calculations certainly give the Boll Worm as much credit as it deserves, and for the following reasons: The observations were made after the cotton had been "laid by" late in July, therefore the fallen bolls collected from the ground in September covered what had fallen during August and September. This is the period of greatest damage to the cotton. No cornfields near by to lessen and detract from the egg deposition on cotton. This in addition to the consideration of the injured fruit actually on the plants but which was likely to shed, certainly does not make the results arrived at much below the entire damage done during that period.

From the results given above and from subsequent observation it is evident that bottom-land cotton is worse infested than the "hill-country" cotton. Further, even in the same field, as is shown by the record of plants 5 and 10 of Table II and plants 12, 16, and 21 of Table III large, rank, leafy cotton plants, bearing a great number of forms and bolls, are subject to much more serious attack.

The number of forms and bolls which one worm may destroy during its period of existence can only be approximated. From the rate of feeding during favorable conditions and when the larval state is about 15 days the number eaten into may range from ten to twenty. During the longer periods of larval existence caused by unfavorable conditions, the worms are inclined to move about more and perhaps injure more individual fruits, though the absolute amount eaten is not much greater.

What the extent of injury due to Boll Worm over the entire State of Mississippi was the past year will be seen from the closing weather and crop report of Prof. R. B. Fulton, observer, U. S. Signal Service,

University, Mississippi, from which is quoted the following: "In the southern part of the State reports show that on account of injury by Boll Worms and shedding, due to wet weather, the cotton crop will be short from 30 to 40 per cent. of last year's yield. * * * In the northern section the Boll Worm did no material damage." It may further be added that upon application to Mr. George E. Hunt, chief signal officer U. S. Signal Service, New Orleans, Louisiana, for weather crop bulletins and the names of observers who had reported much damage to cotton by Boll Worm last season, he replied that no material

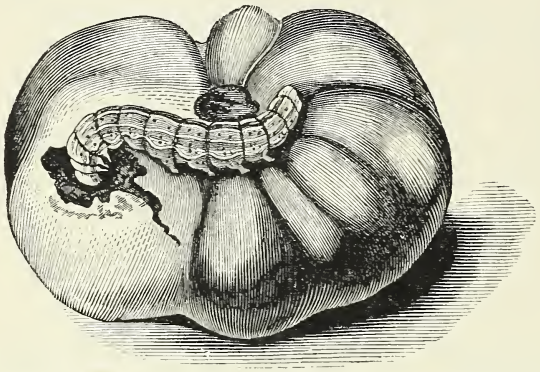

Fig. 1. *Heliothis armigera*; full-grown larva eating into a tomato—nat. size (after Riley).

damage was done from that source and none had been reported by any of the volunteer or other observers. From this information as also the facts shown by the preceding tables it is quite evident that the depredations upon cotton by Boll Worms have been greatly overestimated. If the statements of planters living in the regions where observations were made are accepted, the Boll Worm was fully as numerous if not more so than in previous years. Nearly all agreed that the damage was fully up to the average, others thought it above the normal, but none estimated it as being lower than usual. These statements together with the almost daily reports obtained from interviews that "one-fourth or one-third of the crop was being ruined" (?) led to above careful studies. The results simply show that on the whole the planters fail to distinguish the Boll Worm ravages from those of other insects, from physiological phenomena of the cotton plant, and lastly, from some of the fungoid diseases. In order to assist the planters in this matter a few observations have been added at the close on "Other insect ravages easily confused with those of the Boll Worm."

FOOD PLANTS OTHER THAN COTTON.

Corn.—The habits of the Boll Worm when feeding on corn have been so fully presented in the Fourth Report U. S. Entomological Commission, pp. 359–361, that only such observations will be given as verify

important points or add to our knowledge of the species. The manner of attacking the ears of corn and the semi-solid excrement of the worm which is left behind along its path into the ear, paves the way and provides a fertile soil for the germination and subsequent growth of all kinds of molds. The additional decay resulting in this way, aided by the ravages of Dipterous and other larvæ which revel in such matter, perhaps fully equals the actual damage done directly by the worm. In large fields of corn not often more than one large worm is found in a single ear, but when the fields are small, and especially when surrounded by cotton fields, there are often three or four nearly grown worms in a single ear, and perhaps as many more newly hatched ones. This is a direct result of the preference of the moth for the corn when the latter is in close proximity to cotton fields and of suitable age. When the field is small the female often passes through it several times during a single flight, depositing eggs as she does so. In this way I have often observed the same female deposit eggs three times on the silks of an ear of corn during a single visit. This of course is not the normal method of deposition, and occurs only under the circumstances mentioned. If it were so the numbers of worms would be greatly reduced through the agency of their cannibalistic habits, to be discussed hereafter in considering the history of the worms. Other females visiting the field may also deposit on the same ears of corn, and so on. As a result of this as high as fifteen to twenty-five eggs have been found on the silk of a single ear of corn, and in addition as many more on the husks and leaves.

In regions where corn is cultivated extensively a second crop is planted late in July to produce a fodder crop by the end of the season. These fields are invariably badly infested. When these are near cotton fields they afford a great protection to that crop.

Except on cotton, hereafter considered, no observations of special interest were made on any of the other well-known food plants, though it was noted that the tomato crop suffered severely from Boll Worm depredations.

Other Plants.—As additional food plants of economic importance which are attacked by Boll Worm are to be mentioned the muskmelon, watermelon, and cucumber. The cucumber is attacked usually by eating a hole near the base from below up into the center and then tunneling the length of it to the anterior end. The melons are usually bored from the under side near the base, but occasionally at almost any other point. The female was seen depositing on the following weeds: *Helenium tenuifolium*, *Amarantus retroflexus*, *A. spinosus*, probably *Erigeron canadense*, and one undetermined species of *Panicum*.

It was evident, however, that the young worms did not relish any of the above weeds as food plants and left soon after hatching. This was further verified by taking some branches of the plants just named to the laboratory and placing newly hatched worms upon them. They

fed sparingly upon the small flowers and tender stems, but soon left the branches and could not be induced to remain long. The female shows no inclination whatever to deposit her eggs upon the last-named host-plants except as they may be found in corn fields or near by From here the young worms can easily migrate to the corn plants near at hand, and from observations already cited it is quite probable that they do so. These last observations have, furthermore, led me to suspect that the female may occasionally deposit upon all weeds or other plants indiscriminately growing in a corn field and suitable for this purpose.

CHARACTERS AND TRANSFORMATIONS.

THE EGG.

The egg is oval, the greatest diameter being very near the base. It tapers but little from the point of greatest diameter to the base, but slants much more towards the apex. The vertical diameter averages 0.375 millimetres, the horizontal and greatest diameter 0.5 millimetres. The sculpture of the eggs consists of polar ribs with cross bars, giving them a checkered-appearing surface. When first deposited the egg appears nearly a pure white, but soon turns yellowish as the growth of the embryo begins, and deepens as the latter develops. After about 25 or 30 hours that part of the embryo at the apex of the egg is noticeably darker, and between it and the center of the egg a reddish or brownish band is formed. The latter so far as can be seen extends only part way round the egg.

This band is later absorbed into the body of the worm and the darker spot at the apex is found to be the head of the developing larva. At this stage the body of the worm can be quite definitely seen through the eggshell.

The duration of the egg state varies somewhat, as will be seen hereafter, with the meteorological conditions prevailing at and immediately following the time of deposition. One lot of eggs deposited in confinement at night and followed by two very hot days began hatching within 45 hours. But of a number of lots of eggs deposited in confinement from time to time, the duration of the egg state was usually from 2½ to 3 or 3½ days. This may be considered about the normal duration of the egg state. Several lots, however, which had been deposited during unfavorable weather did not hatch until after 4 days; in a few instances a few hours over 5 days.

THE LARVA.

The newly hatched larvæ, before they have taken any food, average 1.51 millimetres in length, are slightly larger anteriorly, tapering gradually, as is shown by measurements of the diameters of a number of worms at the first, middle, and last segments, whose averages were 0.23, 0.20, and

0.14 millimetres, respectively. The general color of the body is white, with a yellowish tinge; head, black; a black or brownish shield-shaped spot on the dorsal surface of the first segment.

Soon after they begin feeding the larvæ turn darker and before the first molt are usually of a deep rose or brownish color. The piliferous tubercles are not yet very prominent. The true legs at first are slightly

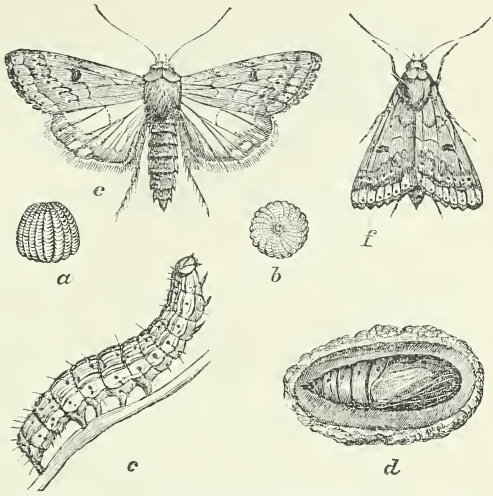

FIG. 2.—*Heliothis armigera*: *a*, egg from side; *b*, do. from top—enlarged; *c*, full-grown larva; *d*, earthen cell with contained pupa; *e*, moth with wings spread; *f*, do. at rest—natural size (after Riley).

dusky, but soon turn much darker, are hairy and provided with a small bifid claw. At first the first pair of prolegs seem to be a little less robust than the others, and hence may be slightly weaker. Obscure dark lateral patches are found on the prolegs, which at this stage are further provided with fine small hooks.

By the time of the first molt the worm has attained a length of 5.62 millimetres and is slightly larger in the middle.

After the first molt the larva is at first of a yellowish color, but again turns darker rapidly when it begins feeding. The true prolegs become much darker, and at their insertion next the body a small dusky spot, both anteriorly and posteriorly, is found. The dark lateral patches on the prolegs are also more distinct, each proleg being now provided with nine small hooks.

By the time of the second molt the larva measures 7.75 millimetres in length and is still a little wider in the middle.

Soon after the second molt the worm measures 8.75 millimetres in length. The most noticeable changes are, that the piliferous tubercles are now much more prominent; that the very small tubercles found thickly scattered all over the body first become quite discernable to the naked eye.

With the three subsequent molts there are no marked changes except in size and the distinctness in definition of the various colorings and markings of the body of the larva.

The mature worm varies in length from 31 to 36 millimetres, with diameters of about 4, 5, and 4 millimetres at anterior, middle, and posterior regions, respectively. The head of the mature Boll Worm is never darker than a light brown, or, in the darker colored worms, mahogany, but may be paler according as the specimen is a lighter colored one. The true legs are dusky or blackish, as also the spots on the prolegs. The latter are now each provided with fifteen small hooks.

The color of the body of the mature worms varies from all gradations of the darker or rose-colored specimens to those which are light-greenish with a faint rose tint or entirely light-greenish. The darker colored ones greatly predominate from about August on through the remainder of the season. The markings of the worms which are most frequently met with at this time are as follows:

Along the median line of the dorsal region is a brownish or blackish stripe containing in its center an interrupted white line. Next, the subdorsal stripe, which is lighter colored, and along which is found the first subdorsal row of piliferous tubercles. Below this is a subdorso-lateral stripe, which is usually about the same color as the dorsal one. The subdorso-lateral stripe is slightly wider at the center of each segment, and within its borders are found two more rows of piliferous tubercles. Next comes the lateral or stigmata stripe, which is usually pure white. Along this stripe are found the spiracles and one row of piliferous tubercles. Between the lateral stripe and the prolegs is a stripe, which is usually of the same color as the ventral surface, which latter is a uniform whitish. This sublateral stripe contains two rows of smaller tubercles. In many of the darker rose tinted specimens this stripe is often nearly a pure rose color, in which case the stigmatal stripe is also more or less tinted. Throughout all the stripes except the lateral and sublateral ones, and in these where they are colored other than white, are found numerous interrupted, irregular, white lines and spots. The stripes are all of a uniform width throughout, with the single exception mentioned. In the lighter colored specimens none but the dorsal and subdorso-lateral stripes can be distinguished at all, and often only the dorsal one.

The first segment is provided dorsally with a denser, calloused part irregularly shield-shaped and which is pale brown or black, according as that is the general color of the worm. In the newly hatched worm, however, it nearly always appears as a very distinct black patch. This calloused portion has a distinct median groove dividing it into two symmetrical halves, each of which bear similar markings as follows:

Four small pits in the form of a trapezoid, the posterior pair being nearest together; from each of these pits extends a fine short hair. In the center and extending each side of the median line are two deep

transverse parallel grooves. At the curved lateral regions of the shield are found slight depressions, and again one at the posterior end of the median line. The shield is further traversed by irregular lines or wrinkles, and in addition contains short white interrupted lines and spots much the same as those found in the stripes of the body. Dorsally the second and third segments each have a transverse row of four piliferous tubercles. The fourth to tenth segments, inclusive, have each four piliferous tubercles, slightly larger than those of the second and third, and are arranged in the form of a trapezoid, the anterior pair being nearest together. On the eleventh segment the four tubercles are arranged in the form of a square; on the twelfth the trapezoid is reversed, the posterior pair of tubercles being nearest together.

Laterally, the first segment is provided with a spiracle about which are two piliferous tubercles. Below there are two smaller tubercles which are usually contiguous and appear much like one tubercle from which two bristles project. The second and third segments each have two large piliferous tubercles, two slightly smaller ones and two still smaller. The fourth to eleventh segments inclusive each bear three tubercles arranged in triangular form about the spiracles with a fourth smaller one below them. The twelfth segment usually has two placed contiguously, or nearly so. Ventrally the tubercles are all small. The fourth segment bears six small tubercles arranged so as to form the arc of a circle. The fifth segment has two transverse rows of tubercles, four in each, the ones in the anterior row being wider apart than those in the posterior. The tenth, eleventh, and twelfth segments each bear a transverse row of four tubercles. All the tubercles throughout have projecting from them a short, stout hair, or bristle.

The growth of the larvæ is somewhat slower during their earlier stages than when half grown and approaching maturity.

When nearing maturity the molts occur at shorter intervals. The intervals between molts become longer later in the season or with cold and unfavorable weather. Thus in August the first molt occurred on the fifth day after hatching, the second on the tenth, the third on the fourteenth, and the fourth on pupation, seven days later. September 25 some eggs began hatching; the first molts occurred on the seventh and eighth days thereafter, the second on the fifteenth and sixteenth days; at this time the particular worms under observation made their escape and the interval of subsequent molts could not be recorded.

The length of the larval state is longer later in the season. Thus at Shreveport, Louisiana, Dr. A. R. Booth reports that during August a worm matured and was preparing to pupate after having fed 15 days; another after 18 days. At Holly Springs, Mississippi, for the same month worms matured within 18 to 20 days after hatching. For September worms hatched about the first of the month, matured in from 21 to 26 days, while larvæ hatched September 25 escaped after 18 days days and had only just molted the second time.

The first food of the worm is the eggshell from which it has just issued. No sooner is the young larva fully out of its shell than it crawls away once or twice its length, turns around, and eats the shell either entirely or but a portion of it. This done it crawls about a short time until it finds a spot suited to its taste, usually first spreading a few threads of a frail web. Under this the worm feeds on the epidermis of whatever surface it may have selected. Often they crawl but a short distance, drop themselves down by a slender thread until another surface is struck, when they crawl away as before and begin feeding.

Before the first molt the larvæ feed principally outside of the young forms and squares on whatever surface they may be when hatched. At about the time of the first molts, or soon thereafter, they begin seeking out the forms, blossoms, and squares and begin their destructive work of boring into them. It must be stated, however, that from the first a few may be found to go directly to a small form or square and either boring through the involucre and thence into the blossom or fruit, or else first crawling between the involucre and fruit and then boring into the latter. Often, too, they at first simply hide behind the involucre, eating the epidermis from the inside and boring into the fruit later. Preferring the tender growing portions of the branches, the younger worms after finding them secrete themselves in the opening clusters of leaf and flower buds and begin boring.

Their first feedings upon the leaves, whether on the upper or lower surface, are principally confined to the epidermis. About the time of the first molt they begin to eat small holes through the leaves. This is not continued long, however, as at this time the worms begin their search for the forms and squares. During the younger period the worms feed most on the reprodutive organs of young forms or such as are nearly grown and opening. Some time later, after about the second molt, they begin boring more plentifully into the larger bolls. The older worms, while feeding principally in larger bolls, do not confine themselves to them and are often found devouring a form or opening blossoms. Due to their choice of food (speaking only of the bulk) the younger worms are found mostly on the younger tender-growing portions of the cotton plant, and the more nearly grown ones on the more mature portions. For a change the full-grown worm sometimes feeds on a leaf or eats through the green stem of a newly formed branch. Stems which were .25–.30 inch in diameter and having above them a number of forms have been observed to be eaten nearly through by them. A day or two after the branch would be found wilted or nearly broken off.

The habits of the worm, as to the manner in which a boll is entered and the extent to which it feeds upon the same after it has entered, are also rather variable. The worm may pass in behind the involucre and bore into the boll from the inside, or it may choose to do so from the outside, eating through the involucre and then into the boll. The hole is usually bored from the bottom and passes towards the apex; fre-

quently, however, the hole is bored about midway of the boll and passes straight in. As the worm thus feeds on the inside of the boll it may pass straight towards the apex, devouring only the section of the fruit which it has entered and then retreat, and attack another boll, or it may bore through the partition into a second section, devouring it, or the passage of the worm may be a slanting one from the first, in which case two or three sections may be entered before retreating. The worm seldom continues until it has destroyed all of the sections of the boll, though the remaining sections are usually made worthless by the decay which arises and spreads from the injured portions.

The notion which some planters have that the worm eats in at one point on the boll and passes out at another is wrong, for if it ever does so it is certainly the exception. Occasionally, however, there are two holes in a boll similar to those which the Boll Worm makes and indeed the Boll Worm has been the culprit. Observation, however, has proven that the Boll Worm occasionally begins boring at one point, eats into it but a short distance, retreats, and begins a second hole at another point on the same boll. Sometimes, also, two worms are found attacking the same boll, which, when they have finished and left it, appears as if a worm had entered at one point and passed out at another.

It is further believed by some that the Boll Worm travels *only* at night and feeds only late in the afternoon and evening. Concerning both it must be said that the worms avoid the extremely hot sunshiny part of the day, and prefer traveling and feeding during the cooler parts; but at the same time considerable range must be allowed for the whims of the worm, and other conditions which may arise to induce the worm to go from boll to boll during mid-day and often at high temperatures. As bearing on this it may be stated that often while making morning observations in the cotton fields worms were found in bolls. Without any disturbance these branches were marked so that they could be easily found for experimental purposes in the afternoon. In the afternoon it was always found that a number of worms had gone to other bolls or even branches on the same plant. Occasionally, too, one would be found to have left the plant entirely and could not be found. The changing of plants was not often done during the day, but was oftener found to be the case with those specimens which had been marked the preceding evening and were looked for the next day. The changing from boll to boll on the same plant may be frequently observed during the day. The time of day when the worms feed most vigorously is during the cooler portions of the afternoon and evening and in the morning before the sun shines so hotly.

After the killing frosts in late October and November the worms which had not yet matured were found to feed as best they could upon the berries of *Solanum carolinense*, and possibly, if forced to, would feed upon any other available green plant found in the cotton fields. Extensive observations on this point could not be made, since the worms

were not at all plentiful. It remains to be added that the larger Heteropterous insects, mostly Metapodius, were abundant upon Solanum at this time, and that probably great numbers of the remaining immature worms fell a prey to them.

The cannibalistic habits of the Boll Worm are also of importance and must be considered here. First to be mentioned in this connection is the fact that the Boll Worm devours its larval skin as soon as molted and does so before it begins feeding on vegetable matter again. When collecting worms from the fields considerable care must be exercised to have a box or basket large enough to receive some foliage, in order that the worms may not injure and destroy each other before reaching the laboratory. In the breeding cages the Boll Worms not only attack each other, but almost any other larva placed in the arena. In a state of nature they have not been observed to deliberately attack each other except in corn, especially when the field was a small one, and great numbers of eggs are deposited and hatched on the same plant, so that an unnatural number of worms expect to feed upon the same ear of corn. The same may be said concerning the "bud," if the plant be young yet.

In several instances where such small fields of corn were found near large cotton fields, examination of the ears resulted in finding from three to six worms of various sizes in them. A day or two later when the same ears were examined some of the smaller ones were found to be badly bitten (enough to cause death), and some dead ones whose bodies gave evidence of a violent death. None of the worms had been devoured, and it seems that the warfare had been brought about by the worms intruding on each other's territory, as feeding progressed, and that nothing more was done than would maintain their positions.

THE PUPA.

A number of Boll Worms which had been fed on bolls in breeding cages matured and were placed in a fruit jar about two-thirds full of earth. The worms at once entered the earth, formed their cells, and pupated about 2 or 3 days after. The pupa is a beautiful green at first, but soon turns to a light brown or mahogany. When all the worms had pupated the earth was examined to determine something about the depth of the burrows and cells and the manner in which they were made. The earth had been recently placed in the jar and was quite loose when the worms were placed on it. The depth of the burrows varied from 2½ to 5 inches and throughout their course were partially filled with loose earth. The cells were all much larger than any part of the burrows and extended upward from the end of the same. One worm had come to the surface of the glass in making its burrow, and was observed while making its cell. The worm seemed to test carefully every part of the wall of the cell to see that all was firm. The whole surface was then thinly coated with a sticky fluid, at the same

time adding a small amount of webbing. The latter was plainly to be seen on the glass of the jar.

Some of the mature Boll Worms which had been left in the breeding cage without earth pupated unprotected on the floor of the same and later issued as moths. In another instance, however, the mature worm had been left in a newly-made breeding cage. The next morning the worm was found to have nicely webbed together the sawdust accidentally left in the corner, and had formed a neat little cell, which might almost be called a cocoon. This shows plainly that the Boll Worm is capable at least of spinning a certain amount of web for its cell, whether it always does so to so great an extent or not.

It was stated above that the worms pupated about 2 or 3 days after having entered the earth. This, however, applies only to the months of August, September, and October. Later the time is longer, as is shown by the following observations: On November 1 a mature Boll Worm from a breeding cage was taken to a cotton field and placed on solid earth, a large open tin can being placed about the worm so as to compel it to make its burrow under observation. The work of digging its burrow was begun at once, and by the next day it had disappeared below the surface. A small conical-shaped mound of loose earth was formed about and over the opening of the burrow. On November 4 two other mature Boll Worms were similarly placed in open cans, the one on solid earth, the other on earth which had been dug up and made very loose. So far as could be seen without digging the burrows were made exactly as the one just mentioned.

On November 14 all the burrows were carefully followed up with a small trowel, to determine depth, condition of the burrows and cells. The worm placed on solid earth, November 1, had proceeded as follows: Down for an inch, then slanting at about an angle of 120 degrees for 2 inches more when the cell had been made upward. The cell was about an inch and a half long, and was therefore within an inch or less of the surface. Very little webbing was noticeable along the burrow, and but little in the cell. The burrow was about 0.25 inch in diameter, larger at the distal end, and contained a small amount of loose earth along its entire length; also a plug of loose earth about 0.25 inch long at the distal end next the cell. Having been in the earth 2 weeks, I was surprised to find that the worm had not yet pupated. The burrows and cells of the other two worms were examined, but no special difference worthy of note was found. The peculiar facts in all were: (1) That the cells were all inclined and higher than the lowest part of the burrow, thus bringing the pupa above the latter; (2) that the cells were so near the surface; (3) that the larvæ were all found with their heads at the upper end of the cell, wherefore the pupæ would have been found with the anterior portion highest and resting on posterior end; (4) that they had not pupated after having been in the earth so long a time.

The duration of the pupal state as noted by Dr. Booth for August to September 2, was 10 to 11 days. At Holly Springs, Mississippi, a number of worms pupated between August 28 and 31. Some of the pupæ issued after 15 days and others not until after 27 days. Two others which had pupated September 4 and 7 issued September 20 and 30, making 16 and 22 days for the pupal state, respectively. Another worm pupated August 31. This pupa was alive, but had not issued at last observation, October 20, when it was injured and died later.

For description of pupa see Fourth Report, U. S. Entomological Commission, p. 371.

THE IMAGO.

For description of the moth see Fourth Report, U. S. Entomological Commission, p. 371.

The sexes of the Boll Worm moth can usually be readily recognized, especially if but a short time has elapsed since their issuance. After the females have deposited most of their eggs and their wings have become worn and battered the sex is less easily distinguished. The body of the female is noticeably more robust than the male; especially the abdomen, which is distended somewhat by the eggs which are being matured. The end of the abdomen is ovoid, acute, the tip not provided with so large a tuft of thick hairs as is that of the male. The abdomen of the male tapering more gradually is slightly longer, of less diameter, and more cylindrical.

When feeding or ovipositing, the flight of the moth is much slower than when flying long distances. The moth approaches a flower or gland, often steadying itself with the fore legs, in any case fluttering its wings rapidly, with antennæ in constant motion. Sometimes they alight to sip sweets, or perhaps to rest; in either case the wings are not closed down upon the body, but are partially spread and elevated, leaving bare the abdomen. If, however, the moth alights to hide, the wings are folded down closely upon the body. Much the same flight is observed in the female when ovipositing, sometimes alighting to do so, but usually only steadying herself with the fore legs. In the act of oviposition, the abdomen is bent forward sickle-shaped, bringing the apex squarely upon the surface to be deposited on. The time occupied in depositing an egg in this manner is equivalent to the time it requires to count three or four slowly. At this rate, and in the interval of flying about from plant to plant, some half dozen eggs are deposited, when the moth is seen to fly away. So far as can be determined these intervening flights are for the purpose of feeding and rest from labor.

Though the habits of the Boll Worm moth have been classed as nocturnal, and they are principally so, yet its diurnal habits are perhaps of geater importance than has hitherto been supposed. During continued daily observations on the Boll Worm in the field the moth was frequently seen flying about, and at times observed to feed. Upon closer obser-

vation it was found that on pleasant sunshiny afternoons the moths flew about quite plentifully, feeding freely during their flight. Often while standing in a patch of cowpeas, from about 3 p. m., have I observed the moths, without any previous disturbance, rise here and there, fly about the pea blossoms or the glands at the base of the young pods, sip their exudations for a few minutes at a time, and then fly away a short distance, alight to rest and hide. In the early part of the afternoon the length of their visits to the pea blossoms are short and the time of their hiding longer than later. About 5 to 6 p. m., when the sun is yet quite high, the moths begin to fly for a longer time and their hidings are of shorter duration.

My own experience with the moth has been that it feeds freely from about 4 p. m. until sundown, when the females begin depositing their eggs, feeding being apparently a minor matter at this time. The moths thus seen flying about in the afternoon are not confined to one sex, though the males predominate during the earlier period until an hour or so before sundown, when both sexes appear presumably in about equal numbers. The favorite food of the moths at daytime are the blossoms and other secreting glands of the cowpeas; they also feed freely on clover and *Helenium tenuifolium*. During the day the moth is seldom met with in the cotton fields either as feeding or by being flushed. It therefore appears that during the day the moth prefers to hide and feed upon plants some distance away from the cotton fields. During twilight and night the moths are found abundantly in corn and cotton fields, and feed almost entirely upon the exudations of the various glands found on the cotton plant.

But not only are the feeding habits of the moth partly diurnal but also those of the deposition of eggs. Though on several occasions a moth was seen depositing eggs on corn, and once on cowpeas in mid-afternoon, the habit is not one of frequent occurrence.

These diurnal habits of feeding and occasional deposition are of great importance in the consideration of the utility of lights as traps for catching the moths at night, and will be taken up more fully in that connection.

The number of eggs which a female may be capable of depositing is difficult of absolute determination, but has been shown to be much greater than was supposed. A female which had issued in confinement was placed in a breeding cage with a male which had issued the succeeding day. Five days after deposition of eggs began, and continued for 7 days. During this time 687 eggs were laid. Unfortunately, the female which was thus under observation after having died became mixed with other dead specimens on the table and hence no dissections were made with a view of determining whether any well developed eggs remained in the abdomen or whether the number of potential ova was great. A female captured August 5, and confined in a box deposited 627 eggs in one night. Another, captured August 8, and

kept in the same manner, deposited 468 in one night. Another, captured August 14, deposited 505 eggs the first night, was kept in a tin box without food during the next day and deposited 125 eggs more on the second night, making 630 in all. The first female spoken of above as having deposited her 687 eggs on seven successive nights did so as follows, beginning with the first night and continuing in order: 49, 5, 10, 436, 147, 22, 18; averaging 98 per night.

The life of the moth was probably shortened by confinement, and therefore the average number of eggs deposited each night is entirely too high for oviposition under normal conditions. The record, however, shows that a climax in egg deposition is reached after a certain period. (The possible importance of this fact is considered under the head of lights as traps for the moth.) The total number of eggs deposited by the four females above noted was 2,413, averaging 603 per moth. But the number of eggs deposited in one night by the moths captured and confined show that their period of greatest egg deposition had already been reached by them. Judging from the record of the moth whose deposition of eggs was observed from the first, it seems safe to suppose that probably each of the other moths had deposited about 50 eggs previous to being captured. This would raise the average to 653 eggs per female. But again, from dissections of the females thus observed in confinement it was found that a number of well developed eggs remained, and usually also a great number of potential ova. The average of 653 eggs per female is therefore certainly not too great and probably much too small.

What the number of eggs deposited in one night in a free state of nature are can only be approximated. As has been stated the female deposits four, five, or more eggs in succession, then flies away, feeds or rests a time, afterwards repeating the process. The interval of nondeposition is necessarily variable, though as near as can be determined about 5 to 15 minutes. How long deposition is continued during an evening is also not to be definitely stated, though it is noticeable that the moths begin to decrease greatly in numbers soon after 8 o'clock, thus approximately the time is about 2 hours. From these data it may be approximated that from about 30 to 60 eggs are normally deposited in a single night. For the nights during the period of greatest deposition, the number deposited is probably much larger.

Upon the number and distribution of the eggs upon the various parts of the host plants the following data are collated: By actual count the number of eggs found on five corn plants is as follows, in averages: per plant, 74 distributed as follows: tassel, 10; leaf sheaths, 10; leaves, 14; husks of ears, 15; silks, 25. The above count was made in a small patch of corn surrounded by cotton fields with no other corn near, wherefore the number of eggs per plant was perhaps greater than on plants in larger fields of corn. (This point will be considered more fully under corn as a protection to cotton, which see.) Of five cotton plants

the number and distribution of eggs in averages was as follows: per plant, 7; leaves, 4; involucre, 1; stem and petiole, each, 1. These are the data for plants examined at random at different times while making observations. Bearing upon the choice of the place of deposition the record of the female already spoken of as depositing in confinement is interesting, and for the whole period of deposition was as follows: on leaves, upper side, 37; under side, 110; stem, 23; petiole, 51; involucre, 4;

The eggs are deposited upon quite a number of host plants. Corn is unquestionably preferable if not too near maturity. Cotton perhaps ranks next, though they deposit freely upon cowpeas. In addition to these the moth was observed to deposit on the flower heads of *Helenium tenuifolium*, *Amarantus spinosus*, and *A. retroflexus* with *Datura stramonium*, upon which the moth feeds occasionally, *Erigeron canadense*, and a species of *Panicum*, on the doubtful list. Deposition was not actually observed on any other host plants, though presumably the moth will deposit on those plants upon which the worm is known to feed.

The food of the moth is quite diversified. During the night, so far as observed, the secretions of the various glands of cotton seem to be their main food, while during the day the same may be said of cowpeas, *Helenium tenuifolium*, and to a lesser degree of newly protruding corn tassels; occasionally, *Amarantus retroflexus*, *A spinosus*, *Datura stramonium*, and perhaps some of the grasses. There may be many other flowers, glands, possibly also fruits, which are visited, but which did not come under observation.

The regular flight of the moth is very swift and never very high. In flying some distance in a cotton field it seldom rises to the level of the tops of the cotton plants, but flies lower, darting this way and that between the plants and foliage in the rows, and in this way from row to row across the field. This manner of flight is also of importance in adjusting lights as traps for them, and is referred to its appropriate heading.

During the greater portion of the day the moths remain hid. If in corn field they are found down behind the sheath of the blades of the stalks, about two or three feet from the ground. But most of the moths hide outside of both corn and cotton fields, around the edges in the weeds, under dried grass and rubbish, or in adjoining fields of clover or cowpeas. When found hiding in these places they are usually upon or near the ground, wings folded upon the body, and so located that a dried blade of grass or other object quite completely hides them from view.

NUMBER OF BROODS AND HIBERNATION.

Observations having only begun in August, the notes taken begin with the fourth brood, which is the one which first begins to deposit freely on cotton.

The broods overlap each other mostly as a result of a difference in the rapidity of growth of many of the worms. One lot of Boll Worms obtained from eggs deposited in a breeding cage by a single female in a single night, and later hatched on the same date, were reared under the same conditions. Some of these worms matured and entered the earth for pupation, while others were yet but half or two-thirds grown. Due to such great irregularity in the length of the larval state fresh females of the fourth brood may be found along with the first to issue of the fifth brood in September. Not much work of the Boll Worm in cotton is noticed until August or early in September. From about the middle of September the moths of the fifth brood begin appearing, and continue to the last of the month, or even the first of October, after which time they are not often met with. At least a partial sixth brood begins appearing late in September and early in October, and consist principally no doubt of those individuals that have undergone their transformations rapidly. That all of the sixth brood does not appear is evident from the fact that they are fewer in number than any of the earlier broods. Hence many of the pupæ of the fifth brood of moths pass through the winter as such and form a part of the first brood in spring. The moths of the last brood appearing so irregularly, worms hatched from eggs of this brood are found in all stages as late as November 20 to December 1. At Shreveport, Louisiana, during this period Boll Worms were found on cotton which had only molted the second time and were therefore only about one-third grown.

But this irregularity in duration of certain stages of the insect is not confined to the larvæ, but to the pupæ as well. Of a number of pupæ which had been kept over from September and October one issued at Shreveport, Louisiana, December 12. Whether the moths, if there be many which issue at this time, hibernate as such or deposit their eggs at once and die soon after, has not been determined positively. If the latter be the case, the progeny will certainly be entirely lost, since no living food plants are found at this period. The Boll Worms which were yet immature at the time of the killing frost early in December were quite certainly destroyed, as nothing remained for them to feed upon. As to whether the moths hibernate, I can only say that close and continued search during December has failed to discover the moth. This may not be surprising, however, since certainly the moths which issue at so late a date, and which would therefore be likely to hibernate, are very few in number, and hence would be met with perhaps only accidentally during the winter season. Though a few moths issue at so late a time as has been mentioned, the other extreme is also met with in the pupal state. Evidence of this is the fact that several pupæ which were obtained from breeding cages late in August had not issued up to November, when they were still alive, but were accidentally injured and died.

It must be kept in mind throughout in speaking of certain stages of

the species that a majority only of that stage is referred to. It should further be remembered that these observations apply only to the northern region of "the cotton belt" and doubtless can be much enlarged upon by observations in more southern portions.

NATURAL ENEMIES.

The fact that the Boll Worm was so scarce during the past season precluded making extensive observations along this line.

Among the vertebrates only circumstantial evidence was obtained. In one instance where the dissevered wings and torn bodies of Heliothis were found under and near a large tree in a cotton field it was also found that a "butcher bird" had its nest on one of the upper branches. Another was the case of a negro tenant, who complained about the crows lighting on his corn plants in the field and eating into the end of the ears. Upon examination it was found that the corn was badly infested with Boll Worm. This alone could not serve to establish the fact that crows picked into the ears for the primary purpose of feeding on the worms. Feeding on the tender grains of corn beneath the husk quite probably an occasional small Boll Worm was eating. It is also probable that still others will be injured by the pecking into the ends of the ears. The crops and stomachs of a number of quails were examined and though they had them shot about cotton fields no Boll Worms were found in these parts of their digestive organs. Upon visiting the fields about which they had been shot no Boll Worms could be found and the negative result has therefore no great significance.

A common species of Soldier bug (*Podisus spinosus*) was found devouring a large full-grown Boll Worm. An immature capsid (near *Leptoterna*) was overlooked and left on a branch of cotton placed in a breeding cage for a female to deposit upon. Soon after deposition some of the eggs showed signs of shriveling and were supposed to be sterile. Close examination, however, led to the discovery of the destroyer, which was as yet but a pupa. The eggs being nearly empty it was evident that the pupa had punctured the eggs and sucked their contents. The same pupa was then placed on a branch of cotton with some newly-hatched Boll Worms, all of which fell victims to its beak. A common species of the robber flies (*Erax lateralis*) was also seen to catch the moth while on the wing.

No observations could be made upon ants in relation to the Boll Worm, since the latter were not abundant enough for that purpose. The ants have been watched on corn for an hour without noticing an attack upon the eggs found deposited there. They are occasionally seen to enter the holes through the husks into the ears, but I did not observe that they went in for the purpose of attacking the Boll Worms. They only sipped freely of the juices and ferments of the injured kernels of corn and the excrement of the worms. Sometimes dead worms are

found in the ends of ears into which ants have entered, but the condition of the worms plainly indicates that they had not been bitten or tormented to death. In fact, worms under similar conditions, except the absence of the ants, are often found, but from which parasites are usually bred. A nearly grown Boll Worm was placed in the path of a great army of ants, but was not caused any great inconvenience by them. Sometimes an ant would run up on the back of the worm, but the twisting, jerking, and rolling of the worm soon displaced the intruder and the worm escaped uninjured.

Of the three parasites, the one attacking the eggs (*Trichogramma pretiosa*) is most important, though there are at least three others attacking the worms. A small Chalcid* was bred in great numbers from a Boll Worm captured in the field and transferred to a breeding cage to rear. The worm had been dead for a day or two before the parasitic larvæ issued from its body. These did not form silken cocoons but pupated nakedly on the side of the glass bottle. At least two species of Tachina deposit their eggs on the backs of the worms. The one deposits a pure white egg, the other a deep brown or black one.†

Both kinds are of the usual form and size of Tachina eggs. Great difficulty has been experienced in rearing the dipterous larvæ after issuing from the dead body and I have thus far obtained no adults.

As already stated, the most important parasite is the small *Trichogramma* of the egg. The number of eggs which were found to be destroyed by this parasite was simply amazing. In small patches of corn near cotton fields it was noticed that of the many eggs found on the husks and blades but a few retained their normal color, but soon turned dark or entirely black. Of the 57 eggs taken from some 8 or 10 corn silks from this field October 18 only 7 hatched. The remainder were kept in a vial for a time, when later the parasites issued in abundance. In this instance 84 per cent of the eggs had been destroyed by the parasites. This per cent may be a little too high for the average, but judging from the large majority of eggs seen on the plants, which were black and evidently parasitized, it is certainly conservative to say that during the Fall season 75 per cent of the eggs are destroyed through its agency.

INSECT RAVAGES EASILY MISTAKEN FOR THOSE OF THE BOLL WORM.

Owing to the fact that many planters attribute all of the shed forms or bolls which show any signs of insect attack to the work of the Boll Worm, it seems advisable to treat briefly of a few other insect depredations which are not well understood by them, and whose marks upon the fallen squares may readily be mistaken by an inexperienced eye.

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*This was *Hexaplasta zigzag*, and is a parasite of *Phora* and not of *Aletia*, *Phora* being a scavenger on dead larvæ of all kinds in the South.—C. V. R.

†No black Tachinid eggs are known, and these were doubtless the eggs of *Euplectrus comstockii*.—C. V. R.

EUPHORIA MELANCHOLICA.

These beetles, together with the four species of larvæ immediately following, are perhaps of greatest importance in this connection. The first observation upon this species was made at Lamar, Mississippi. It led me to believe that the beetles did original boring into the bolls in order to reach the soft parts and their juices inside. Subsequent observations have not verified this opinion. The beetles observed at Lamar were found on a boll with their heads inserted into a small perfectly round hole about an eighth of an inch deep, or just deep enough to reach the soft parts beneath the pericarp. Few Boll Worms had been found in the field, and it seemed quite probable that the beetle had eaten out the cavities themselves. At Holly Springs, Mississippi, where the beetles were found quite plentifully in some fields, none were ever again seen under similar circumstances.

Flying about among the cotton plants during an afternoon they would be seen to alight on some boll which had been recently bored by the Boll Worm, but which had already been deserted by it. Here the beetle would sip of whatever juices there might be coming out of the injured boll. This is quite profuse at times, especially from those bolls of which the Boll Worm has but partially destroyed a certain section. From these proceeds a profuse frothing ferment, highly relished by the beetles, for occasionally two or three may be found at such bolls. When no boll with this tasteful exudate is found, they often alight on the tender-growing portions of a branch where leaf and flower buds may as yet be found but partially developed. They crowd down between these and puncture the tender and juicy peduncles, nearly always attacking those bearing flower buds. The small form supported by this peduncle dries up just as those bored by the newly hatched Boll Worm, and when dried enough to fall readily can not easily be distinguished from young Boll Worm work. With a view of determining whether the beetle ever did original boring upon cotton bolls if left to its choice, a number were placed on branches of cotton in a breeding cage, so as to be kept under observation. The results of these studies during confinement showed plainly that the beetle did its most injurious work by puncturing peduncles bearing forms or puncturing the very small bolls; in either case they were always shed. It therefore appears that if the beetle bores or eats into bolls at all, it certainly is an exceptional method of attack.

PLATYNOTA SENTANA.

The larva of this Tortricid moth is a small, green, slender, hairy worm, having a brown head, and is about half an inch long. It attacks forms and squares much the same as the young Boll Worm does. After the work is done and the worm has gone, its work can not be distinguished from young Boll-Worm ravages. These larvæ continue their

habit of feeding on forms or young bolls until about half grown, when they often migrate to the leaves, fold a portion of them together, and feed under cover. Many, however, remain with the young bolls, and reach maturity by feeding on them. They have been observed to bore half-grown bolls and destroy their contents.

CACŒCIA ROSACEANA.

This Tortricid attacks the cotton in much the same way as the preceding species, and for that reason its depredations may be mistaken for traces of the Boll Worm. The worm differs from the preceding in that the head, dorsal surface of the first segment, and the legs are black.

PRODENIA LINEATELLA.

This fleshy worm was observed entering into nearly grown bolls and feeding on their contents. Its ravages are exactly like those of a nearly grown Boll Worm, and the two can not be distinguished.

NOCTUID (undetermined).

A cutworm, looking much like *Agrotis c-nigrum*, was found in a large breeding cage which had been placed over some cotton plants in the field. When placed over the plants, none of the forms or bolls had been injured, and no Boll Worms were found on the plants. Some time later several large bolls had been bored, and this worm was the only one which could be found in the cage. The evidence is therefore only circumstantial.

PLANT LICE.

(*Aphis gossypii* and *Aphis* sp.)

These small, greenish, mostly wingless, insects were especially abundant during the past season. Earlier in the season they are found principally on the leaves and younger growing portions of the branches, but frequently also on the young bolls between them and the involucre. Later in the season they are found most abundantly in the last-named localities, and in such great numbers on a single form or young boll that the latter soon fall off as a result of their punctures.

In many cases the fruit thus injured simply dries and adheres to the branch. This fact often serves to distinguish it from Boll Worm work. Even when this is not the case their work is readily distinguished in that the form or square contains numerous small punctures.

THRIPIDÆ.

These small brownish insects during August were found in great numbers in the forming blossoms of the cotton plant. The feeding of these insects causes the form to drop soon after the blossom falls, if

not before. Such forms often present small black spots looking like small borings, but which are so numerous that they need not be confused with young Boll-Worm ravages. It must be noted that these signs of mechanical injury are not to be attributed to the Thrips. The shedding of these bolls is probably due to the fact that the work of the Thrips on the essential organs prevents fertilization. This insures the dropping of the fruit.

Many other species of the suborder Heteroptera probably puncture the pericarp of the very young bolls or their peduncles, in either case causing the shedding of the fruit. Careful examination will show that the injury is a puncture and should not be mistaken.

Neither of the first four species mentioned are numerous enough to cause alarm or extended damage, and are only mentioned to show that there is a certain small per cent of injury easily attributed to the Boll Worm which does not justly belong to that species.

REMEDIES.

TOPPING OF COTTON AND ROTATION OF CROPS.

These have both been justly pronounced inefficient as a means of fighting the Boll Worm (see Fourth Report U. S. Entomological Commission). It may be stated, however, that numerous interviews with farmers verified the opinion that topping did no harm, and that if "you could strike it right" it was an advantage. Experimentation is first necessary to show that it is practical and profitable to practice topping of cotton as an additional means of cultivation and the proper time to do so determined. When this is done it will depend largely upon whether that time falls within the period of greatest deposition by the moths. If so, no doubt some additional benefit will be derived by the destruction of the eggs deposited on the parts cut away in topping. But since the moth has been found to have such a wide range of deposition and the portion cut off in topping is so small in proportion to the whole surface of the plant exposed and suitable for deposition, it is not to be recommended to incur the expense of topping when nothing more is to be accomplished than the destruction of the few eggs which are likely to be found on the parts cut away. The rotation of crops can be of no avail against the insect, since it feeds equally well upon the corn or cowpeas, which are most likely to be rotated with the cotton.

FALL PLOWING.

This is to be urged for several reasons. It has been my experience, that where the cells of the Boll Worm pupæ are broken up and placed in loose, moist earth, which is allowed to be moist continuously and possibly to excess, that the pupæ die in a majority of cases even without freezing. It therefore appears that actual contact of the pupa

with the cold moist earth sooner or later may cause its death. From this fact and the long continuous rainy season of the winter here it seems probable that great numbers of the pupæ will be destroyed if the soil be plowed late in December, so as to allow the loose earth to become well drenched by the almost continuous January rains. Subsequent rains will keep it quite wet, often perhaps, to excess. The pupal cells having been broken up, the wet earth directly affects the wellbeing of the pupæ. Even though the exposure to moisture alone should not prove entirely efficient, a light frost or the sudden cold wave changes of the atmosphere would greatly aid in the work of destruction. Certain it is, that a heavy frost occurring when the pupæ are in such condition would destroy all thus exposed. For this reason if the soil could be plowed in November so that the first black frost of the winter season could be utilized in killing exposed pupæ, great benefit would certainly be derived.

CORN AS PROTECTION TO COTTON.

Cornfields planted in July or August were always found to be badly infested with worms. Especially was this the case where the fields were small and near cotton fields. At the same time corn fields no larger but greater distances away from cotton fields were less infested and the cotton more so. As has previously been noted, this is explained by the fact that the moths feed mostly on cotton at night, but leave it to deposit on corn if found suitable and near by. Even late spring planting was found suitable for deposition in August, though maturing rapidly and having nearly grown worms in the ears. Especially suggestive were the observations made in cotton fields where a poor stand had been obtained and where corn had been planted in the "skips." In all cases the moths deposited freely upon the corn, though it was fast reaching maturity. Several of these cotton fields were carefully examined. The most extended search for worms revealed very few indeed, and the only possible conclusion to be arrived at was on the whole that the damage to the cotton was not so great as in those fields without the corn distributed through them. It is therefore evident that by the proper management of the planting of corn the latter could be made to answer as a great protection to the cotton against Boll Worm ravages. This management must consist in arranging the crops on the plantation so that green corn suitable for egg deposition shall be kept near or in the cotton fields in range of the moths.

It must be stated, however, that the corn, which is intended to act as a trap for the deposition of the eggs, and hence of the worms as soon as hatched, must be planted with a view of being cut as fodder as soon as a sufficient number of worms are found in the plants and before the worms begin maturing. From this it follows that the corn, which is to be allowed to mature and produce corn must be planted further away from the cotton fields in order that it may become infested as little as

possible. The importance of this will be appreciated when it is remembered that all the worms which mature on this corn and produce moths will furnish an additional supply to infest cotton and at the same time reduce the number trapped by the corn planted for that purpose. The corn cut for fodder should be disposed of in such a way as to insure the destruction of the worms found in the plants when cut. Each planting of corn which is to act as a trap should be planted soon enough to be in good condition for deposition as each brood of moths makes its appearance. This would require about three plantings for the northern portions of the cotton belt, and probably four in the southern.

The three plantings should occur about the first days of June, July, and August, respectively, and be cut whenever the worms are nearing maturity, to be sure to prevent their escape. By this method the least possible number of worms reach maturity. This consequently reduces their ravages on cotton later in the season to a minimum. This minimum is the most that can be hoped for, no matter what may be the remedial or preventive measures resorted to. This method would furnish a great source of fodder, and would tend to diversify Southern agriculture, a result greatly to be desired.

LIGHTS FOR ATTRACTING THE MOTHS.

Most of the experiments with lights for trapping the moths have proven unsatisfactory so far as economic results are concerned, but have been suggestive in that they have clearly marked out what will be necessary to make the use of lights more efficient.

While at Shreveport, Louisiana, in company with Dr. A. R. Booth, two kinds of patented lamps were taken into a large field of cotton to test their relative values and also to determine if possible the ease with which the moth could be attracted to lights. The lamps were lighted at 6:30 p. m. Quite a number of moths were seen flying about in the field as we passed through it, but up to half an hour after sundown but few insects of any kind were attracted. From that time until 8 to 9 p. m. insects of nearly every description were captured, but no Boll Worm moths. Sometimes a moth would be seen to approach the lamps but was more interested in feeding and depositing, always passing by or around without apparently noticing the lamps.

The lamps had been placed on pedestals high enough to bring them above the level of the top of the cotton plants, hoping thereby to attract moths from greater distances. In the mean time it was noted that the moth seldom attained to such a height during her flights about the cotton plants. Accordingly, on the evening of August 8, the same lamps were taken into the field, but placed so as to meet the habits of flight of the moth. This placed them at least on a level or a little below the plane of the top of the cotton plants. It was found that more moths approached and came nearer the lamp, and one was caught. In most cases, judging from the flight and actions of the moths, the lamps

were simply met with in their regular flight through the field for the evening, and that their course had not been materially influenced by the lights. Despite this fact, it was evident that the probabilities of trapping the moths at this height were increased. To vary the experiment, the lamp was carried through the field at about the height just mentioned, and one person walked along on each side some distance from the lamps so as to disturb the moths in that vicinity. In this way still more of the moths came near the lamps, and another one was caught. This is impractical, however, since the expense of labor is too great, at least until some means of making the lights more efficient is effected.

One of the lamps was provided with a shield constructed so that it would revolve with the wind, and thus prevent the lights from being blown out. This is entirely wrong, since the moth usually flies with the wind, in which case the light is of course shut off from view entirely. This defect renders the lamp entirely worthless for the end desired. In our experiments this shield was held or made stationary, and hence the defect did not enter or vary the significance of the results.

At Holly Springs, Mississippi, lamps were placed in cotton fields at various times during August. Some consisted merely of beer bottles filled with kerosene and a piece of unraveled cotton rope for a wick, and others of more powerful lamps. In all cases the lamps were placed in pans containing an inch or so of water, with a little oil on the surface, the whole being placed on a supporting pole or pedestal. The beer-bottle lamps burned satisfactorily, produced a good light, and attracted insects of nearly every order and kind except the Boll Worm moth, though these had been seen flying about in the field late in the afternoon.

On the night of September 9 these lamps were again taken into a cotton field having a small patch of corn near by; also a large patch of weeds, principally sneeze weed (*Helenium tenuifolium*). A lamp was placed in each at about the level of the tops of the plants, except the one in corn which was placed on about the same level as the ears on the plants. By 5 o'clock the moths were seen flying plentifully and ovipositing freely. The lamps were lighted at 6:15 o'clock. No insects of any kind were attracted until 7 o'clock, when moths of all kinds began flying near the lamps. By 7:15 a Boll Worm moth had been caught at the lamp in corn. At 7:25 at the lamp in cotton a Boll Worm moth flew near the lamp, alighted on the pedestal and rested. From here it flew up to a small boll in the direct light of the lamp, deposited an egg and flew off. From this time on many Ichneumonids and other Hymenoptera, as also great numbers of Microlepidoptera were caught. At 7:40 a Boll Worm moth was seen to fly through the flame of the lamp but was not captured. In corn at 7:50 a moth flew about the lamp and alighted on a blade of corn less than 2 feet away. For this act of defiance it was introduced to the cyanide bottle. Not many

moths were seen between 8 and 9 o'clock but the lamps were left burning all night to determine what would be the nature of the catch by the next morning. At this time the catch was examined and the results are tabulated below. For convenience the lamps in *Helenium*, corn, and cotton will be numbered 1, 2, and 3, respectively.

TABLE VII.

Hymenoptera.

	Ichneumonidæ.	Miscellaneous.	Total.
1	10	4	14
2	9	3	12
3	12	2	14
Total for all			40

Lepidoptera.

Lamp.	Agrotis.	Heliothis.	Spilosoma.	Miscellaneous Noctuids.	Geometridæ.	Pyralidæ.	Pterophoridæ.	Miscellaneous.	Total
1				17	15			300	332
2	2	1		1	30		27	300	361
3	1		1		25	20	26	250	323
Total for all									1,016

Diptera.

Lamp.	Tipulidæ.	Miscellaneous.	Total.
1	8	25	33
2	40	10	50
3		75	75
Total for all			158

Coleoptera.

Lamp.	Epicauta.	Scarabæidæ.	Elateridæ.	Staphylinidæ.	Carabidæ.	Miscellaneous.	Total.
1		2	2	25	8	25	62
2	7				2	50	59
3	2	1			6		9
Total for all							130

Hemiptera.

Lamp.	Homoptera.	Heteroptera.	Total.
1	200	100	300
2	200	100	300
3	200	150	350
Total for all			950

TABLE VII—Continued.

Neuroptera.

Lamp.	Chrysopa.	Total.
1	1	1
2	1	1
3		
Total for all		2

Orthoptera.

Lamp.	Mantis.	Œcanthus.	Locustidæ.	Total.
1	1	2	2	5
2	1	2		3
3	2			2
Total for all				10

The above results show that the direct benefit to cotton plants, so far as known, is very small. At the same time such beneficial insects as the Ichneumonids, predaceous beetles, and the Praying Mantis are destroyed, and if trapping be systematically followed up the loss may indeed be considered greater than the gain.

These experiments led to the belief that the lights used were not brilliant enough for the intended purpose. Accordingly, an electric lamp was rented. The lamp is provided with a round burner and the flame produced is about 5 inches in circumference. When the chimney is placed over the flame the lamp is said to give a light equal to 100 candles. Experiments with this lamp in connection with the others were continued in the cotton fields during September. On the evening of the 13th both kinds were placed out. The night proved to be a damp cold one, and the dew fell early in the evening. As a result no Boll Worm moths and but few insects of any kind were trapped. Of this small number the parasitic Hymenoptera and predaceous beetles were greatly in the majority. The insects caught were such as are easily attracted to lights, and were quite equally distributed between the three lamps (two beer-bottle ones and the other the electric lamp). A rainy season began at this time and continued so that no further experiments with lamps could be made until October 4. At this time the electric lamp was placed in a cotton field to determine what would be the nature of the catch. Heliothids had been seen flying about in the evening while making some other observations, but none were captured by the lamp at night. The other insects trapped were about the same in kind as those already tabulated for September 9, only that the quantity captured by the electric lamp was about equal to that of all three of the others, and it had only been left burning until 10 o'clock.

October 20 the lamps were again placed out, this time one in a patch of cowpeas and the other some distance away in a small patch of corn which had been planted in July. During the day Boll Worm moths

were seen hiding behind the sheaths of the corn blades, while a number were also seen flying about the cowpeas. The one in the cowpeas was a beer-bottle lamp and placed about the height of the plants. The one in the corn was the electric lamp, and was placed about the height of the ears of corn. They were lighted at 6 p. m. At this time a few of the females were depositing on corn. At 7 o'clock some were seen to fly by the lamp but were not trapped. The parasitic Hymenoptera and smaller Lepidoptera had been caught in great abundance at both lamps. Returning at 10 o'clock to further examine the catch of the lamps, they were found to have been stolen and no further notes could be taken. The moths at this time were not very abundant and doubtless were but a portion of the last brood of the season. The moths seen flying by the electric lamp were near enough to have been stopped had the lamp been provided with long projecting wings and a larger pan to receive the moths as they fell. No Heliothids were observed at the beer-bottle lamp.

These light experiments, as will be seen from the record, were begun at the time that the midsummer brood was issuing abundantly, and hence also during the period of greatest egg deposition a little later. During this period, as has been stated, the provoking observation was made of seeing the female near the lights, deposit an egg in plain view, fly away and continue her work. It is evident, therefore, that the female is not easily diverted from the work of depositing eggs by the ordinary lights used. Later, when the experiments show that a few moths were trapped, it is also true that the period of greatest deposition had passed, and that, though dissections showed that a few eggs still remained together with a number of potential ova, the females had passed their prime. As bearing on this the following may be drawn from the observations of Dr. Booth : The insect contents of a globe of a 2,000 candle power arc light were examined continuously from September 3 to 13, inclusive. An average of 40 Heliothids were found for each night. Of these 1 in 6 or 8 were females, containing on an average from 30 to 40 eggs in the oviducts. The lamp tender reported that after September 26 no more moths were caught.

The fact that the moth was frequently seen to fly near the light, often as near as 2 or 3 feet, suggests that the lamps to be efficient not only must be brilliant, but must also have some wide and extensive wings extending from it in such a way as not to throw a shadow and to arrest, temporarily at least, the flight of the moth passing near by. If now the large pan and the lamp be provided with an additional inducement in the way of some strong smelling sweets, the moth thus arrested in its flight and its attention diverted from its evening work, if not falling into the pan, may be attracted a second time and be captured.

Unless it is found that the earlier broods are more easily attracted to lights it is questionable whether the inefficient lights so commonly used

by planters are to be at all recommended if nothing more is to be accomplished than the trapping of the Boll Worm moth, and for the following reasons: (1) But a small per cent are caught; (2) of these the great majority are males; (3) while some females are caught before having deposited many eggs, the greater per cent have passed their prime; (4) beneficial insects being more easily trapped are destroyed in too great numbers in proportion to the benefit derived from the destruction of obnoxious insects to warrant such inefficient warfare. These may all be included in the one general reason that the lights are only strong enough to readily attract beneficial insects but are powerless to attract the obnoxious insects desired until its most important work (deposition of eggs) has almost been completed.

POISONED SWEETS.

No field experiments were made with poisoned sweets, but a number were made with moths in the laboratory. The mixture was composed of 1 part of white arsenic dissolved in 20 parts boiling water; 4 parts of this solution were added to 3 parts of ordinary table sirup. The mixture was placed in a watch glass under a bell jar or sprayed upon cotton branches in a breeding cage. When the moths were placed in they always soon found the sweets and sipped of them. The result of all the experiments showed that the moths readily partook of the sweetened liquids. Those having sipped of the poisoned solutions died, on an average, within 30 minutes; the shortest time being 15, the longest 45 minutes. Experiments were also made upon a few other insects, mostly such as were considered beneficial. They were placed in the cages just as the moths had been and were found to partake of the sweets quite as readily and died as certainly. Thus in field experiments doubtless many beneficial insects will also be destroyed by the extensive use of the poisoned sweets.

The moths kept in cages for experimental purposes were fed by spraying unpoisoned solutions of the sweets upon the cotton branches. The moths fed readily and lived usually from 5 to 8 days.

The poisoned sweets used in the experiments in the laboratory contained no liquids which could liberate a strong odor such as is necessary in field experiments. These may be added in the form of beer or vinegar or perhaps any other liquid having similar properties.

It was demonstrated by the experiments in the laboratory that newly issued and old moths were alike easily induced to feed on the poisoned drops of sweets sprayed on the branches in the cages. It may therefore follow that if these poisoned liquids can be properly applied to the plants upon which the moths feed freely both at night and during the day, that females may be readily attracted to feed, and hence killed, during their entire period of deposition. It therefore appears probable that if some practical means is employed to apply these poisoned sweets properly and abundantly as food for attracting the moths that such

method of warfare against the adults will prove more efficient than any other alternative yet resorted to against them. It is evident, however, that to be most efficient, the poisoned sweets must be applied from the time when the moths begin feeding freely, and in such a way that they may meet with them readily in their flights about their food plants. The first will be accomplished if applied as early as 4 o'clock in the afternoon, in which case the poisoned liquids would also be exposed to their visits during the evening and night. The second can be attained by spraying the poisoned liquid upon the food plants. For those moths feeding during the day this must be applied principally to cow peas, for those feeding at night upon cotton.

The practicability of this method is yet somewhat questionable since probably one application of the poisoned liquids would be efficient only for a few days. It may further be questioned in that, as has been noted, the moths of any given brood issue quite scatteringly. At the same time it may be that applications of the poisoned sweets at intervals of 3 or 4 days will prove to be as practical as arranging for, and attending to, *light trapping* properly. My own efforts to experiment fully along this line were rather frustrated by rainy weather during September. This made experiments difficult and more or less indecisive.

The possible utility of combining poisoned sweets with lights has already been noted. The fact that females are readily attracted by sweets before many eggs have been deposited by her may become a sufficient additional inducement to entice those flying so near the lamps to linger a few moments longer and probably result in her capture. With these probabilities in mind it is to be hoped that the approaching season may be more propitious for experimental work and the Boll Worm more abundant.

PYRETHRUM.

Experiments with the dry powder.—The first of the following series of experiments with pyrethrum were made upon infested corn. The patch of corn was about two rods square and located near the center of the town (Holly Springs, Mississippi). It was a second planting and was only knee high at this time, August 19. The middle rows of the patch were selected and one row for each experiment taken. The powder was dusted from above down into the bud of the corn by means of a small cheese-cloth sack, double thickness.

Experiment 1.

August 19, 2:30 p. m. Mixture, equal parts lime dust and pyrethrum. The plants in the row by actual count contained 43 worms of various sizes.

Result.—Soon after dusting a few acted uneasily, began to crawl, and finally dropping to the ground, hid in the loose earth. This note applies more or less to all the experiments made with the powders. August 20, 10 a. m., 17 worms alive and feeding, 10 dead, 16 not present. In percentages this is 39.5, 23.3, 37.2, respectively. The living worms were mostly nearly mature ones which had penetrated far into the center of the bud and may not all have come in contact with the powder. The dead

ones were mostly composed of half or two-thirds grown worms. These notes again apply equally well to nearly all the other experiments with the powder. The following experiments will therefore be given more concisely.

EXPERIMENT 2.

August 19, 3 p. m. Mixture, 2 parts lime dust, 1 part pyrethrum. Number of worms in plants, 43.

Result.—August 20, 11:30 a. m., 20 living, 10 dead, 13 not present, or 46.5, 23.3, 30.2 per cent, respectively.

EXPERIMENT 3.

August 19, 3:30 p. m. Mixture pyrethrum full strength. Number of worms 54.

Result.—August 20, 12 m., 25 living, 8 dead, 21 not present, or 46.3, 14.8, 38.9 per cent, respectively.

EXPERIMENT 4.

August 19, 4 p. m. Mixture equal parts lime and pyrethrum. Worms not counted.

Result.—August 20, 2 p. m., 19 living, 12 dead, or 61.3 and 38.7 per cent, respectively.

EXPERIMENT 5.

August 19, 4:30 p. m. Mixture 2 parts lime, 1 part pyrethrum. Worms not counted.

Result.—August 20, 2:30 p. m., 26 living, 8 dead, or 76. 5 and 23.5 per cent, respectively.

EXPERIMENT 6.

August 19, 5 p m. Full strength pyrethrum. Worms not counted and only a part of the row dusted.

Result.—August 20, 3 p. m., 5 living, 6 dead, or 45.5 and 54.5 per cent, respectively.

The dead worms of experiments 1 to 6 were kept, for raising any possible parasites, until September 3, when they were found to be perfectly dry and were thrown away. No parasites had issued from them.

As checks on experiments 1 to 6 it may be stated that in examining the rows carefully to count the actual number of worms in the plants no dead worms were found. Numerous other observations upon corn of a similar age, and which had not been dusted, verified the one made while counting the worms.

The first 6 experiments and their results may be tabulated for convenience as follows:

TABLE VIII.

Experiment.	Substance used.	Living.	Dead.	Absent.	Probable benefit.
1	Lime and pyrethrum, equal parts	39.5	23.3	37.2	60.5
2	Lime 2 parts, pyrethrum 1 part	46.5	23.3	30.2	53.5
3	Pyrethrum, full strength	46.3	14.8	38.9	53.7
4	Same as experiment 1	61.3	38.7	.....	38.7
5	Same as experiment 2	76.5	23.5	.....	23.5
6	Same as experiment 3	45.5	54.5	.....	54.5
	Averages	52.6	29.7	17.7	47.4

EXPERIMENT 7.

August 20, 10:45 a. m. Dusted the 17 living nearly-grown worms of experiment 1 with full strength pyrethrum, and placed them in a closed mailing box without food.

Record—11 a. m., some are beginning to be restless; 12:30 p. m., all are quiet; 1:45 p. m., one almost dead, others jump when touched; 4:20, p. m., one dead, others as before.

August 21, 11:30 a. m. Somehave becon e quite active again, and as a result 4 were bitten, 3 are dead, 6 others alive and active, while the rest were probably eaten. The active ones were placed in a breeding cage, and provided with branches of cotton having leaves and bolls. Some died later and a few matured.

EXPERIMENT 8.

August 30, 4:30 p. m. Eighteen of the living worms from experiments 4, 5, and 6 were well dusted with lime. Nine were placed in each of two closed mailing boxes. This experiment was for the purpose of having a check on any possible effect of the air-slacked lime on the worms.

August 21, 11:45 a. m. In one box two were injured and died. The rest alive and active. In the other box all are well and active. Both lots were then placed on branches of cotton in breeding cages. All began feeding; a few died later, but most of them matured.

EXPERIMENT 9.

September 11. Boll Worm in a boll with posterior segments protruding. Dusted this with full strength pyrethrum at 9:15 a. m.; no immediate effect was noticeable; 11:30 a. m.; worm has turned round; head almost protruding; not feeding; 3 a. m., has turned round now to position same as when dusted, and is feeding. With a pair of forceps placed some pyrethrum powder on the body of the worm in the hole. Did not effect the worm noticeably for five to ten minutes.

September 12, 8:30 a. m. Has left the boll and is in the upper corner of the cage still alive and active.

September 13, 8 a. m. Has returned to the boll it had left, and is feeding. Dusted the protruding portion with pyrethrum. In the afternoon the worm was found crawling about in the cage, but appeared to be full grown and searching for a place to pupate. Placed back on the branch again.

September 14. Worm still on the boll and is active, but not feeding. Particles of pyrethrum are found adhering to the body. The anus is swollen and inflamed, producing a watery exudate. This may be due to the effect of the pyrethrum, for this is the portion of the body which was usually protruding from the hole in the boll and received most of the dusting. The worm was placed in a partially opened form.

September 15. Has eaten the form almost entirely.

September 16. Crawling about in cage. Placed on a branch.

September 17. Crawling about in cage. Has shortened some and is preparing to pupate. Placed in a tin can with earth to allow it to do so. Pupated September 21. Pupa still alive October 3, when it was placed in alcohol as a specimen.

In one instance, when a worm had been experimented with in a similar way to Experiment 9, the worm went down to corner of the cage (which was a newly made one), webbed together the loose sawdust found there, and pupated in the cell thus formed.

EXPERIMENT 10.

September 20, 5:30 p. m. Marked five bolls in which Boll Worms were feeding and a portion of the body protruding. At 5:40 dusted profusely with pyrethrum, full strength.

6 p. m. The first worm ceased feeding and left; can not be found. The second was entirely in boll, but came out and is twisting about uneasily; finally it fell to the ground in convulsions, tumbling over on its back as if to scrub off the powder. The third ceased feeding. The fourth was a young worm and is not to be found. The fifth still feeding.

6:15. The second is still in convulsions and can not crawl well; it is one about two-thirds grown. The third has fallen to the ground, but is crawling into loose earth. The fifth continues feeding. The last two are nearly grown worms, and doubtless will take some time to become badly paralyzed. At 6:30, while making other observations, it became dark, and could not find the worms again.

A number of individual experiments with grown worms, both in the laboratory and open air, were made. The worms were well dusted with full-strength pyrethrum and were allowed their pleasure as to their abode afterwards. They always crawled into the loose earth as soon as possible, and as long as they were observed showed signs of recovery. Other experiments similar to Experiment 9 are omitted because their results were practically the same in all cases.

DECOCTIONS OF PYRETHRUM.

Seven pints of rain water were brought to boiling in an open pan; 12 grains of pyrethrum were then stirred in and boiled for 15 minutes. The whole was then strained so as to get out most of the powder. This decoction was made on the afternoon of September 19, but owing to a threatening rain was kept in sealed Mason jars until the next day, when the decoction was sprayed on bolls containing Boll Worms. The following strengths were used: Full, two-thirds, and half.

Experiment 15.

September 20. The bolls with worms in had all been found and marked during the forenoon. The day was warm and sunshiny. In the afternoon it was found that one of the worms had changed bolls since morning observation. At 2:40 p. m. full strength of the decoction was sprayed on each of six bolls containing Boll Worms. Four of the six were not in bolls, but between them and their involucres. The greater portion of the plants surrounding the boll was also sprayed.

2:50. No uneasiness manifested by any.

3:15. Five as before; one half-grown worm has moved and can not be found.

3:45. No change; has not affected the worms yet.

4:10. None feeding; no change.

5:00. One feeding; others as before.

5:50. None feeding.

September 21. Two worms still in place; one feeding, the other just molted; two others finished the bolls in which they were found and have disappeared; the other one is in boll in laboratory.

September 23. All have gone but one; this one went to another boll, fed, and has just molted; an hour later it was found devouring molted skin.

Experiment 16.

September 20. Equal parts decoction and rain water. At 3 o'clock sprayed five bolls, each containing a Boll Worm. Four were not feeding, but resting between boll and involucre; the other was in boll feeding. None had changed position since morning observation.

3:25. One seems to be a little uneasy; others manifest no anxiety.

3:42. The one in boll has turned around and is poking its head out of the bolls; another has moved and gone into a blossom; the others same as before.

4:10. One is feeding; all the others quiet and not feeding.

5:00. One feeding; others no change.

5:50. None feeding.

September 21. Four still in place, all feeding; the other has left the plant.

September 23. One still in place, but has about destroyed its boll. The others have done so and are gone.

The record of the experiment with two parts decoction and one part rain water is omitted because of the similarity of results to those of Experiment 16.

Checks on Experiments 15 and 16.

September 20. At first three, but later five more worms were marked as checks.

2:30. One entirely in boll, feeding; another, nearly mature, resting and not feeding; a third, very young one, is feeding.

5:00. Checks all in place feeding.

5:50. All but very young one feeding. Made a search for more worms; found five, all of which are in bolls feeding.

September 21. One still in boll, but not feeding.

The small worm has bored through a form and is feeding. The nearly matured worm has destroyed its boll and has gone away.

The result of all the experiments with pyrethrum is, on the whole, negative. Before treating more fully of the results of the experiments it must be stated that the corn plants, cotton bolls, and Boll Worms were more thickly and thoroughly dusted or sprayed than it would have been possible to do by dry method of application which would be inexpensive enough to be practical. There is a special difficulty in the case of cotton. At the time when the powder would be most efficient, that is, when the worms are yet less than half grown, they are found principally at work in forming blossoms and very young bolls. In these the involucre so completely and effectually inclose the portions in which the worms are at work that it is practically impossible to reach them. It is well known that the young form or boll is sensitive to excessive rains, and their involucres, it seems, are to a great extent a provision of nature to protect the tender young bolls from such injury. To whatever extent this may be the case, it is certain that their involucres make it exceedingly difficult to reach the forms and bolls beneath them by any of the methods of spraying, and therefore also to all decoctions or solutions of whatever kind.

Upon corn before it has tasseled the powder may be used with greater success, as will be seen from a study of Experiments 1 to 6. From these we find that a certain benefit of about 30 per cent. is obtained, with a possible benefit of about 47 per cent. This last is too high, however, as some of the worms which leave do so only temporarily and to recover, after which they return. We also find that the young worms are much more susceptible, or at any rate less able to resist the effect of the pyrethrum. Consequently of the worms killed, the great majority were half or less than half grown. From the behavior of the grown or nearly

mature worms in all the experiments, it is evident that they strongly resist the effects of the powder, and if ample opportunity is given to escape to the ground or loose earth, may often entirely overcome its influence and recover. Whether on corn or cotton, it must be admitted that the protection is only temporary. This is shown by the fact that in some of the experiments undisturbed individuals entered bolls with impunity soon after dusting and after the first worm had retreated, or even the same worm going back and feeding upon the boll from which it had been driven, presumably, by the pyrethrum.

As has been noted, there is a certain benefit derived from the application of the powder to young corn before tasseling. It is just to consider that the pyrethrum was at a disadvantage, in that it was not applied early enough to catch the worms before they had become so nearly grown or had entered far into the bud. If it had been applied earlier a much greater per cent of the worms then present would doubtless have been destroyed. Such being the case, the use of pyrethrum may prove to be a decided advantage in coöperation with the plan of planting corn as traps for egg deposition, and hence the worms when these are hatched. This can be done by thoroughly applying pyrethrum of about one-half or third dilution with lime to the corn plants at a time when the worms are found to be about half grown. By doing this the time of cutting out corn to destroy the worms it contains will be delayed for a time longer, and hence also be exposed to the depositions of the moth for a greater period. Experiments in this direction will be taken up extensively this season.

The powder being thus limited in its efficacy, especially on cotton, it is not surprising that decoctions of the powder prove to be even less effective. As will be noted from the experiments with the decoctions when compared with the record of the checks upon the same, little more was accomplished than to temporarily arrest the feeding of the worms. It is true some of the worms changed bolls during the afternoon, and others which were in bolls came out, but it must also be noted that the same action was taken by other worms which were under observation and which had not been sprayed. There is some question, therefore, that the decoction was directly accountable for the action of the worms upon which it was sprayed.

This doubt is further increased from the fact that it was often noted in worms which had been marked for observation that they very frequently changed bolls or even plants during midday or afternoon.

OTHER VEGETABLE INSECTICIDES.

The work upon vegetable insecticides was assigned almost entirely to Prof. Jerome McNeill, Fayetteville, Arkansas. He has been as unfortunate as myself in being unable to obtain plenty of Boll Worms to experiment with. Progress was further impeded by unpropitious weather. For this reason the greater portion of the time was occupied in collecting

such roots, plants, flowers, and fruits as might, upon experimentation, prove to have insecticidal properties. This was undertaken with a view of discovering if possible some product easily grown in the infested regions through the cultivation of which it might be possible to provide for an insecticide which would be cheap and accessible to all. From these various collections Professor McNeill has made numerous extracts, emulsions, and decoctions, some of which he informs me are quite promising, and which are on hand to experiment with when opportunity offers. As this part of the work has, therefore, not been completed for the reasons stated, I shall at present give only a summary of Professor McNeill's letters and report of progress during the past season.

(1) Alcoholic extracts and decoctions have thus far been, on the whole, unsatisfactory.

(2) Extracts and extract emulsions of the various vegetables or parts thereof seem to be promising. Of these kerosene, kerosene ether, gasoline and benzine extracts, and emulsions of pyrethrum are perhaps most important.

(3) Of the plants experimented with, *Lobelia syphilitica*, *L. cardinalis*, probably *L. inflata*, and *Arisæma triphyllum* are among the more important as giving promise of good results. They have been shown to possess insecticide properties, but to what extent and how best utilized remains an open question.

(4) An exceedingly dilute solution of potassium cyanide is an efficient insecticide, but its effects on the cotton plants has not yet been determined.

METEOROLOGICAL CONSIDERATIONS.

Of these rain, humidity, and temperature are the principal phenomena to consider. What relation these may have to the various stages of the transformations of *Heliothis*, the following tabulated data may serve to indicate. The averages of humidity and temperature are given for the entire period covered by each example:

TABLE IX.

EGG.

When deposited.	When hatched.	Duration.	Rain, number of days.	Temperature.		Humidity.	
				Max.	Min.	Max.	Min.
				°	°	°	°
Night, Aug. 5–6	Aug. 10, 10 a. m	3½	3	93	74	88	56
Night, Aug. 8–9	Aug. 10, evening	2	0	94	73	87	63
Night, Aug. 14–16	Aug. 18, 9 a. m	3½	1	84	72	(*)	(*)
Night, Aug. 15–16	Aug. 18, 9 a. m	2½	0	84	72	(*)	(*)
Night, Sept. 19–20	Sept. 24, evening	5	5	79	67	(*)	(*)
Night, Sept. 20–21	Sept. 25, morning	4½	5	78	64	(*)	(*)
Night, Sept. 21–22	Sept. 25, morning	3½	4	77	67	(*)	(*)

* Data for humidity at Holly Springs, Miss , could not be obtained. The first two are from Shreveport, La., where eggs were under observation.

TABLE IX—Continued.

LARVA.

When hatched.	When matured.	Duration.	Rain, number of days.	Temperature.		Humidity.	
				Max.	Min.	Max.	Min.
				°	°	°	°
August 9	August 23	15	1	91	71	88	65
August 10	August 25 (died)	16	2	91	71	88	67
August 18	September 7	21	6	82	68	.....	.....
August 18	September 12	26	7	82	68	.....	.....
September 25	October 12 (two molts)	18	7	73	60	.....	.....

PUPA.

When pupated.	When issued.	Duration.	Rain, number of days.	Temperature.		Humidity.	
				Max.	Min.	Max.	Min.
				°	°	°	°
August 9	August 20	11	0	91	71	89	65
August 23	September 2	10	2	91	68	82	60
August 28	September 12	15	5	81	68	.....	.....
August 28	September 13	16	6	80	68	.....	.....
August 28	September 16	19	8	79	67	.....	.....
August 28	September 17	20	8	79	67	.....	.....
August 31	September 27	27	14	79	66	.....	.....
September 4	September 20	16	7	80	67	.....	.....
September 7	September 30	22	15	79	68	.....	.....

These data may be studied in the order given.

EGG.—For the first two lots the temperature is the same with only a slight difference in humidity, but during the period of the first lot rain fell for a part of the time on 3 successive days; during the second none fell at all. Under these conditions the duration of the first lot was 1½ days longer. The period covered by the next two lots of August 15 and August 16, furnish about the same conditions with the same results. The next three lots were deposited much later in the season, had lower temperature and excessive rains, 6.37 inches having fallen from September 22 to 25 inclusive. The duration of the egg state as a result was much prolonged. There is no check on this lot, however, since no eggs under direct observation were hatched during that season with the same low temperature but without the excessive rains. From general observations, however, there is no question but that low temperatures also prolong the duration of the egg state, the same as the rains seem to have done in each of the two first lots mentioned.

Larva.—The first two larvæ were reared under almost exactly similar conditions and, as will be seen, matured almost at the same time. As compared with those that follow the duration is of interest, as there was but little rain and a high temperature. The next two were worms hatched from the same lot of eggs, and, as is seen from the table, were reared under exactly similar conditions. Despite this, the difference in time of maturing is 5 days. This can only be accounted for by the peculiarities of the species, such as have been previously discussed. The difference, as compared with the two preceding, was principally due to the much lower temperature. If, with the abundant rain during that

period, the temperature had been maintained as high as in the first, the worms would have matured more rapidly. This is verified by noticing the retardation of growth of the last worm recorded in the table. This worm had only molted twice after 18 days. The temperature during this period was 18° lower than that of the first two and 9° lower than that of the second two. General observations established this fact concerning the feeding of the worms, viz: that a moderate amount of rain with high temperature was least suited to their most vigorous feeding and growth, and consequently their earliest maturity. The same amount of rain, however, with a much lower temperature, is as much a disadvantage, and increases the retarding effect, which the lower temperature itself would have had. But again, high, dry temperatures are avoided by the worms, which during that time feed less vigorously, and thereby prolong their larval existence some.

Light frosts began (both in Mississippi and Louisiana) as early as October 27, and were more or less continuous from that time on. At Holly Springs, Mississippi, a killing frost occurred October 31, which froze and entirely blackened the cotton plants. At Shreveport, Louisiana, however, the cotton was not entirely frozen and blackened until about December 4. As has been previously noted, worms of nearly all stages were found at both localities a short time previous to the killing frosts, by which latter the younger ones were quite certainly killed.

Pupa.—For the first of the pupæ recorded it is found that a moderate amount of rain with high temperature shortens the duration of the pupal state. From the remaining ones it is found that with but little variation in the low temperature, which alone would have prolonged the duration, the excessive rains greatly added to the delay.

In general, then, it may be stated that the duration of the various stages of Heliothis are shortest under high temperatures with moderate rainfall; longer, except in egg and pupa, when a high, dry temperature is maintained; longer still with much lower temperature; and yet again longer with lower temperature and excessive rains.

Some atmospheric conditions also noticeably influence the behavior of the moths. The hot weather, dry, or somewhat rainy, seems to have but little diverting effect on the habits of the moths. When the temperature is much lower, and is accompanied with much rain, the moth adapts itself to the condition of things. The excessive rains last season continued late in the evening and into the night. This of course covers the period of feeding and deposition. This seemed to have the effect of inducing the moths to fly and feed more freely during the middle of the afternoon, when it was clear and warmer. When the rainy spell began to be a protracted one, the females were frequently seen at 3 o'clock during the warm sunshiny afternoons busily engaged in depositing their eggs. The instances in which deposition was observed in daytime were confined mostly to this period, though some were observed under normal conditions. From this it follows that to a certain

extent, at least, the imagos adapt themselves to unfavorable conditions, and that their period of egg deposition, on the whole, is not much influenced by such conditions. Their progeny, however, as has already been noted, suffers materially.

As bearing on the abundance (or rather scarcity) of the Boll Worm the past year, I quote from the report of Professor Fulton for 1890 as follows: "The most important irregularities of the year were the unusually high temperature in January and February, with a marked deficiency of temperature in March." During the period of high temperature in January, and especially February, it may be that many of the moths issued. If so, the cold period in March quite likely killed many of those which had issued. In the Red River section of Louisiana the Red River overflowed badly in spring, and planting of both corn and cotton was delayed until late in May and some in June. This necessarily delayed finding suitable host plants for the moths which had issued during April and May to deposit on, and doubtless a large per cent of their progeny failed to survive. In some localities also corn and cotton had been planted and was large enough for the moths which had issued to deposit upon when the river overflowed. As a result the corn and cotton both were drowned, or at any rate stunted so that it was all plowed under and planted a second time. By this process doubtless many of the first brood of worms were destroyed. From these reasons the second brood and consequently all subsequent broods were in all probability greatly reduced.

From all the information gathered through observers of the U. S. Signal Service it is certain that the boll-worm depredations are much more extensive in the southern portion of the cotton belt. There is, therefore, no question but that the future work on the Boll Worm should be carried on principally in that region.

INSECT DISEASES.

The work upon insect diseases has formed an important part of the investigation. At the present time, however, it would be unwarranted and hazardous to enter largely into a report upon the work done and in contemplation, or to draw conclusions. I shall therefore give but little more than a synopsis of the present condition of the work, and will reserve acknowledgments to those who have contributed in any way for a more detailed report in the future.

The first thing to be done in preparing for such work was to equip and arrange for a bacteriological laboratory. Some time was spent at Shreveport, Louisiana, in coöperation with Dr. Booth (who assumed charge of the work for the season) towards accomplishing this end. Hot-air and steam sterilizers were designed and a good workman soon had them in condition for use. The other supplies immediately necessary were ordered. These have been added to as the progress of the

work demanded, until now quite a complete laboratory has been fitted up, sufficient to carry on to a finish all the work and experimentation which it will be possible to execute.

The diseased insects and worms from which the cultures on hand have been made were obtained from various sources from entomological workers throughout the country.

Extensive and conclusive experiments with the insect diseases on hand were not made for the same reasons stated by Professor McNeill. The status of this portion of the work is, therefore, much the same as the latter, viz, ready for extensive and thorough work during the approaching season. The few observations made are encouraging, but do not warrant any definite and positive statements at this time.

It seems highly probable that the Boll Worm is readily susceptible to the cabbage-worm disease. Dr. Booth in one instance fed Boll Worms upon diseased cabbage worms, which Boll Worms later died. Cultures were obtained from these dead Boll Worms. Mounts from the cultures were made later and studied with a microscope. Micrococci were present in great abundance. At Holly Springs, Mississippi, some Boll Worms were accidentally placed in a breeding cage in which dead cabbage worms had been temporarily placed. A number of these Boll Worms died at various intervals. The dead worms were sent to Dr. Booth, who made cultures from their dead and decaying bodies. Examination of mounts made from these cultures again showed micrococci in abundance. The above evidence is not direct and positive; is merely indicative, and at best unscientific. It consists simply of observations noted during the progress of the work, and simply indicates that scientific experiments may prove successful.

Though no experiments could be made upon the Boll Worms with *other* insect diseases, the interesting and important discovery was made at Holly Springs, Mississippi, that the Boll Worm itself is subject to a disease. The disease is not confined to the larval stage, but has been obtained from all the stages of the species. Two females issued on the night of September 14. On the second day, it was noticed that the moths were rather sluggish and that the abdomen was greatly distended. By the next day the females were absolutely helpless, and the abdomen so decomposed that it barely held together while pinning the moth. The last signs of life of the moth consist of peculiar alternate openings and closings, contracting and expanding of the anus and genital organs. At the time it did not occur to me that it was a disease of the species, and it was only the peculiar manner of the dying of the moth which had attracted my attention. Hence it was that the moths were simply pinned and placed in insect boxes. This was done September 17. November 28, the abdomen of the moth was accidentally broken off and the internal parts were found to be partially liquid. From this partially liquid portion tubes of beef broth were inoculated, as also from a whitish, waxy, gelatinous substance in the extreme poste-

rior end of the abdomen. A culture was obtained from the waxy portion, and the microbe is different from any of the others studied. It is possible that the cultures obtained from the moths after so long a time are non-pathogenic microbes, instead of the one which produced the disease of the imago. No positive statements will therefore be given until experiments have been made. Cultures from the egg, larvæ and pupæ are in stock, and, so far as examined, are all exactly alike. This disease can not have been mistaken for any other, since it was noted before any of the others were on hand. Thus, having probably found the Boll Worm subject to a disease perhaps peculiar to itself, it remains to be seen whether it is contagious and easily disseminated for infection.

In addition to this, a disease of each of the two larvæ whose ravages are easily mistaken for those of the Boll Worm was also discovered at Holly Springs, Mississippi. The two species are *Prodenia lineatella* and the undetermined Noctuid spoken of. In fact the disease of each was so prevalent, that but few of the worms were found, and of those found all but one, which had been placed in alcohol, died of the disease. No great apprehensions need therefore be had concerning these two species.

Diseases of *Agrotis messoria*, *Nephelodes minians*, as also of the large tomato worm, are at hand in the form of cultures.

Cultures from all these sources were begun in August, 1890. By the regular methods for such work pure cultures have now been obtained and are transferred from time to time to fresh media, in order to continue the healthy growing germs through the winter and in good condition for the approaching season's experimental work. In this way a vast number of cultures in fine condition are on hand, and it is to be hoped that abundant opportunity may be offered this season to execute extensive and thorough experiments.